A Synopsis of the IEEE P1451- Standards for Smart Transducer Communication

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Abstract:
This paper discusses the objectives of the IEEE 1451 and its family of one approved and three proposed standards for smart transducer communication, as well as who should use them, how users should benefit from the implementation, and up-to-date development status and contact information. In an ideal world, decisions about field devices, field networks, and application software can all be made independently based on the application requirements. In the real world, however, all these modules can not be easily integrated due to the lack of a set of common interfaces. Therefore, this paper also describes how the family of IEEE-P1451 standards, with digital communication protocols, digital interfaces, and object model for smart transducers, can provide a means for sensor producers, system integrators, and users alike to develop network-independent solutions for distributed measurement and control applications.

Keywords: actuator, communication standard, IEEE 1451, interface standard, interoperability, sensor, smart sensor, TEDS.

Introduction

The sensor market is extremely diverse. Sensors are used in most industries, for example, aerospace, automotive, biomedicine, building, industrial control, manufacturing, and process control. Sensor manufacturers are seeking ways to build low-cost, smart sensors to meet the continuous demand for more sophisticated applications and ease of uses. Networking is becoming pervasive in all areas in industrial countries and is causing a key shift in the measurement business [1].

The rapid development and emergence of smart sensor and field network technologies have made the networking of smart transducers (sensors and actuators) a very economical and attractive solution for a broad range of measurement and control applications. However, with the multitude of incompatible network specifications that have been created, a certain degree of confusion and uncertainty has arisen about which network(s) to support. It is clear that a variety of networks will exist to solve specific problems. However, it seems that industry is in a crossroad and this predicament has imposed unnecessary economic burden to both transducer end users and vendors to support the variety of networks. This condition has also impeded the widespread adoption of these technologies despite a great desire to build and use them.

In view of this situation the Technical Committee on Sensor Technology of the Institute of Electrical and Electronics Engineer (IEEE)'s Instrumentation and Measurement Society has sponsored a series of projects, designated as IEEE P1451, to address these issues through the development of a family of

smart transducer interface standards for connecting transducers to networks [2]. When these standardized interfaces are in place, transducer producers can design their devices to a single set of specification for transducers and networks connectivity. This will hopefully alleviate the uncertainty and allow for the rapid development of smart sensors and actuators for use with the networks [3]. In the long run, it will most likely lead to a lower development cost for the smart sensor producers and a proliferation of smart devices in the market. Thus, the emergence of smart devices and control networks will make available a wide variety of products for users to choose from based on their merits. If this trend continue, it will eventually lower the total system cost and broaden the application domain for distributed control applications for the users [4].

Objectives of 1451

The objectives of the IEEE P1451 projects, Standards for Smart Transducer Interface for Sensors and Actuators, are to define a set of common communication interfaces for connecting transducers to microprocessor-based systems, instruments, and field networks in a network-independent environment.

The projects are to develop hardware and software standardized connection methods for smart transducers to control networks utilizing existing control networking technology. There are no set requirements for the use of different analog-to-digital converters, microprocessors, network protocols, and transceivers. This in turn will reduce the industry's effort to develop and migrate to networked smart transducers. The ultimate goals of the standards are to provide the means for achieving transducers to network interchangeability and transducer to networks interoperability.

The 1451 Family

There are currently four standards projects under development in the Sensor Technology Committee [5]. A diagram showing the relationship of the family of standards is shown in Figure 1.
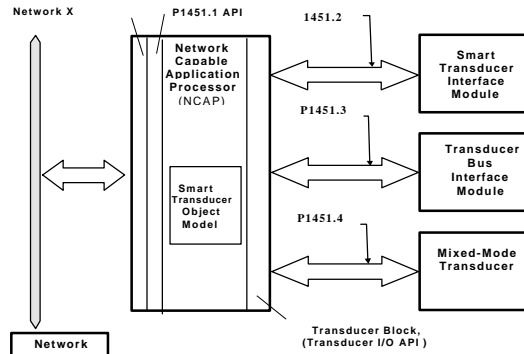

Figure 1.   The IEEE P1451 Family Relationship.

1. IEEE P1451.1, Network Capable Application Processor (NCAP) Information Model

This project is to develop the definition of a common object model for the components of a networked smart transducer and the software interface specifications to these components [6]. Some of the components are the NCAP block, function block, and transducer block.

The networked smart transducer object model provides two interfaces.

- The interface to the transducer block which encapsulates the details of the transducer hardware implementation within a simple programming model. This makes the sensor or actuator hardware interface look like an io-driver.
- The interface to the NCAP block and ports encapsulate the details of the different network protocol implementations behind a small set of communications methods.

Application-specific behavior is modeled by function blocks. To produce the desired

behavior the function blocks communicate with other blocks both on and off the smart transducer. This common network-independent application model has the following advantages:

- Establishes a high degree of interoperability between sensors/actuators and networks, thus enabling "plug and play" capability.

- Simplification of the support of multiple sensor/actuator control network protocols.

The P1451.1 working group has supplemented its work with experimental implementations in "C" and "C++" to ensure the implementability of the specification [7]. The working group has just completed the balloting of a second draft of the proposed standard [8].
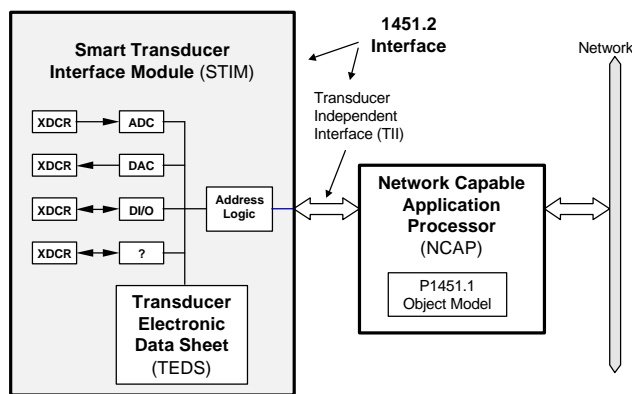

Figure 2. System Block Diagram Showing the P1451.1 and 1451.2 Interfaces.

2. IEEE P1451.2, Transducer to Microprocessor Communication Protocols and Transducer Electronic Data Sheet (TEDS) Formats

This project defines a TEDS, its data format, and the digital interface and communication protocols between the transducers and microprocessor [9][10]. The TEDS, stored in a nonvolatile memory attached to a transducer, contains fields that describe the type, attributes, operation, and calibration of the transducer. With a requirement of only 256 bytes of memory for the mandatory data, the TEDS is fully scaleable. A transducer integrated with the TEDS provides a very unique feature that makes possible the self-identification of transducers to the system or network. Since the transducer manufacture data in the TEDS always goes with the transducer and this information is electronically transferred to a NCAP or host, human errors associated with manual entering of sensor parameters into the host is totally eliminated. Because of this distinctive feature of the TEDS, upgrading transducers with higher accuracy and enhanced capability or replacing transducers for maintenance purpose is simply "plug and play".

The 1451.2 Standard was developed in a very practical manner with demonstrations of its implementation during its draft development. Silicon support and commercial prototype implementation of the IEEE Std 1451.2-1997 are available now [11-13]. The 1451.2 Standard, designated as IEEE Std 1451.2-1997, has begun its publication. It can be purchased from the IEEE Standards Office [14].

3. IEEE P1451.3, Digital Communication and Transducer Electronic Data Sheet (TEDS) Formats for Distributed Multidrop Systems

The P1451.3 project is proposed to develop a standard digital interface for connecting multiple physically separated transducers in a multidrop configuration. There are several issues that need to be resolved when trying to make the nodes on a bus self-identifying. The most obvious problem is to define a protocol that will allow all devices on a transducer bus to identify themselves. Other problems involve the speed of operation when powering up a bus. When powering up a bus for the first time, the time that it takes to begin operation is not critical. However, in some environments where short power dropouts occur, the time that it takes to get back into operation is critical. The

protocol being developed in the working group is an attempt to address these issues. In order to enhance noise rejection, a spread spectrum over wire technology developed at the Oak Ridge National Laboratory is proposed and being discussed in the working group for inclusion in the draft document.

4. IEEE P1451.4, Mixed-mode Communication Protocols and Transducer Electronic Data Sheet (TEDS) Formats

In the machinery conditioning monitoring industry analog transducers like the piezoelectric transducers, piezoresistive transducers, and strain gages, for example, are used with electronic instruments to measure the conditional state of machines. Traditionally, transducer measurement is sent to a computer for analysis. The transducer companies embrace the idea of having small TEDS with their analog transducers and connecting the transducers to a network. However, they prefer to minimize the number of wires by using the same two wires for analog signal transmission for communicating the digital TEDS data to instruments or NCAPs as well. The draft standard in progress will define an interface for mixed-mode transducers - bidirectional communication of digital TEDS data for self-identification and control and then change into analog signal mode of operation [15]

Application of 1451 at NIST

At the National Institute of Standards and Technology (NIST), research work is continuing on defining a framework for the various levels of an Internet-based distributed measurement and control (DMC) system. The framework targets three important areas of standardization including transducer interfaces, open network communication, and distributed application development. An implementation of a DMC application on the Internet based on the 1451 draft specifications was done [4]. Another DMC application using 1451.2 technology is also being planned for the tele-measurement and calibration of gas flowmeter via the Internet [16]. A schematic is illustrated in Figure 3 to show the connectivity of the clusters of pressure and temperature sensors and the digital flow rate control valves to the 1451 nodes. Compressed air, regulated to a specified flow rate set by the digital flow control valves, is flowed through the flowmeter under test (MUT). The exhausted air, collected at the collection vessel, is weighted to determine its mass. The flow period, which is precisely monitored, is calculated with the mass of the air to come up with the flow rate. The flow assessment unit, consists of four pairs of ultrasonic flow sensors, determine whether the flow pattern in the pipe is uniform enough for the measurement to be valid. The 1451 nodes used will be Ethernet-based. Sensing and control functions will be executed at the node level. Calibration procedure and data collection will be controlled by an operator running a host computer.
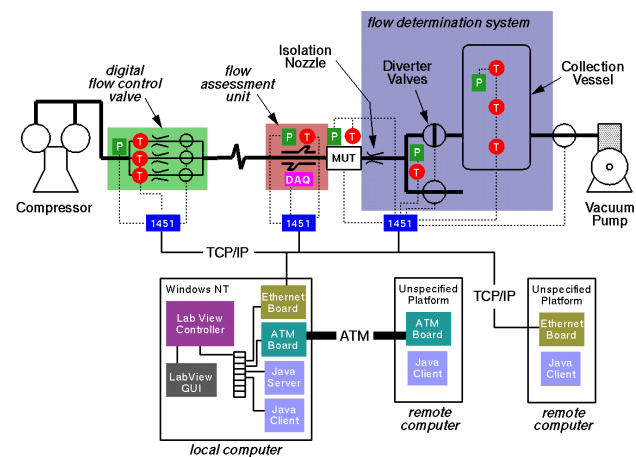

Figure 3. Schematic of tele-calibration of gas flowmeter.

Summary

The smart transducer interface standards' hardware specification, IEEE 1451.2, provides the enabling technology to ease the connectivity of transducers to microprocessors, control and field networks, as well as data acquisition and

instrumentation systems. The standardized TEDS specified by 1451.2 allows the self-identification of sensors and actuators to the networks and systems. The TEDS and the common digital communication interface, provide a standardized mechanism to facilitate "plug and play" of sensors to networks. The combination of 1451.2 and the upcoming P1451.1 standards will define the specification for networked smart transducers. The network-independent approach of P1451.1 will allow sensor manufacturers to easily support multiple networks and protocols. Thus transducer-to-network interoperability is in the horizon. With the addition of P1451.3 and P1451.4 to the family of 1451 standards it will fulfill the needs of the analog transducer user and provider communities. Since 1451 provides the enabling technology for self-identification of transducers, it will also facilitate self-configuration, long-term self-documentation, easier transducer upgrade and maintenance, and increased data and system reliability. In the long run, transducer vendors and users, system integrators, and network providers can all benefit from the 1451 interface standards.

References

1. Minneman, Michael. " Realizing the Benefits of Networking Demanding Measurement," Proceedings of Sensors Expo Boston, May 13-15, 1997, pp 51-56.

2. Bryzek, Janusz. "Summary Report," Proceedings of the IEEE/NIST First Smart Sensor Interface Standard Workshop, NIST, Gaithersburg, Maryland, pp. 5-12, March 31, 1994.

3. Travis, Bill. "Smart-Sensor Standard Will Ease Networking Woes," EDN, pp. 49-55, June 22, 1995, Cahners Publishing.

4. Lee, Kang and Schneeman, Richard. "Distributed Measurement and Control Based on the IEEE 1451 Smart Transducer Interface Standards, " to be presented in the Instrumentation and Measurement Technical Conference '99, Venice, Italy, May 24-26, 1999.

5. Travis, Bill. "Sensors Smarten Up," EDN, pp. 76-86, March 4, 1999, Cahners Publishing.

6. Lee, Kang. "The Proposed Smart Transducer Interface Standard," Proceedings of the Instrumentation Measurement Conference (IMTC)' 98, St. Paul, MN, May 18-21, 1998, vol. 1, pp. 129-133A.

7. Warrior, Jay. "IEEE-P1451 Network Capable Application Processor Information Model," Proceedings Sensors Expo Anaheim, pp. 15-21, April 1996, Helmers Publishing.

8. "IEEE P1451.1 D2.25, Draft Standard for a Smart Transducer Interface for Sensors and Actuators - Network Capable Application Processor (NCAP) Information Model," Institute of Electrical and Electronics Engineers, Inc., Piscataway, New Jersey 08855, January 25, 1999.

9. Lee, Kang and Schneeman, Richard. "A Standardized Approach for Transducer

Interfacing: Implementing IEEE-P1451 Smart Transducer Interface Draft Standards", Proceedings Sensors Expo Philadelphia, pp. 87 - 100, October 1996, Helmers Publishing.

10. Woods, Stan. "IEEE-P1451.2 Transducer to Microprocessor Interface," Proceedings Sensors Expo Anaheim, pp. 9-14, April 1996, Helmers Publishing.

11. Woods, Stan *et al*. "IEEE-P1451.2 Smart Transducer Interface Module," Proceedings Sensors Expo Philadelphia, pp. 25-38, October 1996, Helmers Publishing.

12. Johnson, Robert. "Building Plug-and-Play Networked Smart Transducers," Sensors Magazine, pp. 40-46, October 1997, Helmers Publishing.

13. Johnson, Robert. "IEEE 1451.2 STIM Implementation and Support for Transducer Manufacturers," Sensors Expo Proceedings, ADT1: Smart Sensors & Smart Sensor Communication, pp27-36, October 5, 1998 Helmers Publishing.

14. "IEEE Std 1451.2-1997, Standard for a Smart Transducer Interface for Sensors and Actuators - Transducer to Microprocessor Communication Protocols and Transducer Electronic Data Sheet (TEDS) Formats," Institute of Electrical and Electronics Engineers, Inc., Piscataway, New Jersey 08855, September 26, 1997.

15. Chen, Steven and Lee, Kang. "IEEE P1451.4- A Proposed Smart Transducer Interface for Mixed-Mode Communication." *Sound and Vibration Magazine*, pp. 24-27, April 1998.

16. Espina, Pedro. "Tele-Metrology: Remote Flowmeter Calibration," Flow Control, Vol. 5, No. 1, pp. 16-21, January 1999.